IPCC GREENHOUSE GAS ACCOUNTING AND AGRICULTURE

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SUMMARY

The International Panel on Climate Change (IPCC) has produced the 1996 Revised Guidelines on National Greenhouse Gas (GHG) Inventories, which provides detailed information about how countries are to report GHG emissions on a sector by sector basis. In 1997, the Kyoto Protocol changed the IPCC accounting guidelines for agricultural soils. In Article 3.3, the Protocol limited activities that can act as carbon sinks to specific forestry activities, thereby excluding agriculture as a sink activity. The exclusion of agricultural sinks is a disadvantage to Canada, because the adoption of zero tillage and other soil-conservation farming systems is increasing carbon stores in agricultural soils. Removals of carbon in agricultural soil sinks could be used to offset emissions from other sources.

Policy makers should be aware that the IPCC inventory data, being sectoral, is not suitable for policy development or analysis in agriculture, which is a cross-sectoral activity. Policy to address emissions reductions from agriculture needs to be based on net GHG emission data from whole farming systems.

1. BACKGROUND

1.1 Institutions

In 1988, in response to the rapid rise in atmospheric concentrations of greenhouse gases compared to pre-industrial levels, the World Meteorological Organization and the United Nations Environment Programme established the IPCC to do research and provide information about the science and policy issues surrounding climate change. Its first report on climate change, its causes, impacts and possible response strategies was published in

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1990. That report provided the basis for the negotiation of the United Nations Framework Convention on Climate Change (FCCC) which was ratified in March 1994.

The long-term goal of the FCCC signatory countries, or the Conference of the Parties (CoP), is to *"stabilize atmospheric concentrations of greenhouse gases at a level that will prevent dangerous anthropogenic interference with the climate system"*. The FCCC requires that countries *"develop, periodically update, publish and make available to the CoP, national inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gas, using comparable methodologies"*. The CoP meet annually. In Geneva in 1996, the CoP endorsed the conclusion of Houghton et al. (1995) that there is evidence of *"discernible human influence on the global climate"*. The third meeting of the CoP in Kyoto, Japan in December, 1997 resulted in the Kyoto Protocol which sets forth emissions reduction targets for CoP developed countries. Canada's emission reduction target is six percent below the 1990 emissions level. Emission targets are to be achieved during the first commitment period of the CoP, which is 2008 to 2012.

1.2 Greenhouse Gases

The IPCC developed a set of instructions, the Revised 1996 Guidelines, for the accounting of anthropogenic GHG emissions for national inventories. The guidelines cover flows of three GHG, carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), from human activities to the atmosphere. How flows of those gases are affected by agricultural activities is discussed below.

1.2.1 The Carbon Cycle and CO_2. There are four components of the carbon cycle that involve agricultural activities: CO_2 in the atmosphere; organic carbon in plants and animals; stored organic matter carbon in soils or trees; and fossil fuels. The first two components are regarded as carbon flows in the short-term carbon cycle, and the latter two are carbon stocks.

Carbon Flows. Carbon dioxide moves between the atmosphere and plants and animals in a cycle driven by two major processes: photosynthesis and respiration. Photosynthesizing plants convert atmospheric CO_2 into organic carbon which is returned to

the atmosphere as CO_2 when plant materials are respired (consumed by animals or decomposed by microorganisms). It is assumed that flows of CO_2 from respiration will taken up by plants in the next growth cycle and are not net additions to the atmosphere.

Carbon Stocks. Carbon stocks are organic carbon that is removed from the carbon cycle and stored. Examples are soil organic matter carbon, fossil fuels and the biomass in forests. The decomposition of soil organic carbon when soils are cultivated, the extraction and burning of fossil fuels, and the harvest and consumption of trees each represent a decrease in the size of the carbon stock and a net emission of CO_2 to the atmosphere. The release of carbon from these stocks, which were sequestered for millennia, has caused the increase in the atmospheric concentration of CO_2.

1.2.2 The Carbon Cycle and CH_4 Methane is part of the carbon cycle, but whereas CO_2 is released from the respiration of organic material, CH_4 is released when organic matter is decomposed in environments that lack O_2 (i.e.anaerobic conditions such as wetlands or the guts of ruminant animals). There is no biological sink for CH_4; carbon released into the atmosphere as CH_4 is not in a form that can be used by plants or animals. The major sink for CH_4 is a reaction with OH in the troposphere and its lifetime in the atmosphere is about 11 years (Watson et al., 1990). Methane has a GHG warming potential 21 times greater than CO_2.

1.2.3 The Nitrogen Cycle and N_2O Most nitrogen in the atmosphere is N_2, which higher plants and animals cannot take up directly for synthesis of the proteins and other molecules they require for life. There are two natural pathways, lightning and legume plants, convert atmospheric N_2 into forms that plants can use for production of organic nitrogen compounds. The manufacture of nitrogen fertilizers for agriculture is another pathway for the conversion of N_2 into plant available forms. Smil (1997) estimates that about one third of the protein in the human diet now depends on synthetic nitrogen fertilizer.

Decomposing plant residues and nitrogen fertilizers can result in the emit N_2O, which has a warming potential 300 times that of CO_2 . Once N_2O is in the atmosphere its only

sink is photochemical decomposition in the stratosphere. The release of N_2O from agricultural activities is considered a net emission to the atmosphere.

2. GHG ACCOUNTING FOR NATIONAL INVENTORIES

Three international bodies and their documents describe accounting protocols for national GHG inventories: *i.* the Revised 1996 IPCC Guidelines; *ii.* the 1997 Kyoto Protocol; and *iii.* the eighth report of the Subsidiary Body on Scientific and Technological Advice (SBSTA8) to the CoP in 1998. Inconsistencies among these groups has made accounting for GHG emissions and removals is a confusing and uncertain process. Differences between the IPCC guidelines and the Kyoto Protocol regarding the potential for carbon sequestration and CO_2 removals in agricultural soils have created particular uncertainty about GHG accounting for agriculture. The protocols and differences among the three organizations are discussed in the next sections.

2.1 Revised 1996 IPCC Guidelines

The Revised 1996 IPCC Guidelines for national GHG inventories are organized by sector: energy, industrial processes, solvent and other product use, agriculture, land-use change and forestry (LUCF), and waste. Because agriculture is a cross-sectoral activity, emissions related to agricultural activities are accounted for in several sectors. Sources from on-farm crop production are counted in the agriculture sector, emissions from production inputs (fertilizers, fossil fuels) are counted with the industrial and energy sectors, and carbon stocks and changes in stocks of soil organic carbon in agricultural soils are part of the LUCF sector.

2.1.1 Agriculture Sector Accounting. On-farm crop production activities are a source of CH_4 and N_2O. Emissions or removals of CO_2 from crop production are assumed to occur as part of the carbon cycle (photosynthesis or respiration) rather than from a change in carbon stocks. As such, net emissions of CO_2 from crops are assumed to be zero.

The IPCC accounting for agriculture is based on emissions of CH_4 and/or N_2O from: *i.* enteric fermentation and manure management associated with domestic livestock

production; *ii.* field burning of agricultural residues; *iii.* agricultural soils from nitrogen fertilizers, animal wastes, nitrogen fixing crops, crop residues; cultivation of organic soils; deposition of nitrogen with precipitation; and *iv.* rice cultivation and prescribed burning of savannas, which do not apply to Canadian agriculture.

2.1.2 LUCF Sector Accounting. Net emissions or removals of CO_2 from changes in soil organic matter or forest carbon stocks are accounted for in the LUCF sector. The amount of organic carbon in stored in agricultural soils or in forest biomass is assumed to vary depending on land management practices and changes in land use. Specific land use activities included in the LUCF sector are: *i.* land use change and forestry activities, including changes in forest stocks, which can result in either CO_2 emissions or removals; *ii* forest and grassland conversion which reduces the carbon stock and results in CO_2 emissions; *iii.* abandonment of managed lands which increases the carbon stock and represents a CO_2 removal; and *iv.* land use change and management, which includes agriculture and can result in either net CO_2 emissions or removals.

The IPCC guidelines outline a method for estimation of CO_2 emissions and removals from agricultural soils (Houghton et al., 1996). It is based on soil carbon stocks and areas of major categories of agricultural land management, and assumes that for a particular farming system, soil carbon levels tend toward an equilibrium state over time. At equilibrium, carbon inputs from crop residues and losses through decomposition roughly balance. When land moves from one form of land use or land management to another, there is a change in the carbon stock and an associated net flux (either an emission or a removal) of CO_2.

Some members of the CoP questioned current ability to measure changes in carbon stocks in agricultural soils (the amount of organic carbon in soils is large and variable, and its rate of change under agricultural land uses is slow). As a result, the CoP limited sink activities to forestry in the Kyoto Protocol, a decision which has created uncertainty about accounting for changes in carbon in agricultural soils.

2.2 The Kyoto Protocol

The CoP, in Article 3.3 of the Kyoto Protocol, agreed to limit LUCF sink activities to reforestation, afforestation and deforestation (RAD), specifically excluding CO_2 removals in agricultural soils. Other decisions of the CoP at Kyoto, however, have made the issue of agricultural sinks less clear than would be expected from Article 3.3: *i.* Article 3.4 of the Kyoto Protocol allows for future discussion on the inclusion of other land uses, such as agriculture, as sinks activities; and *ii.* Decision 2 of the Addendum to the Kyoto Protocol, which outlines actions taken by the CoP states that *"Parties should use the Revised 1996 Guidelines for National GHG Inventories of the IPCC to estimate and report on anthropogenic emissions by sources and removals by sinks of GHG"*

Thus, the CoP has endorsed the revised 1996 guidelines of the IPCC, in which agriculture is considered a land use with sink potential, and at the same time, has limited sink activities to RAD. Article 3.3 also contradicts the clearly stated intent of the FCCC that each country shall " *limit its anthropogenic emissions of greenhouse gases and* ***protect and enhance its greenhouse gas sinks and reservoirs***".

In summary, the Kyoto Protocol: *i.* by limiting sink activities to RAD, provides no incentive for the enhancement of GHG sinks and reservoirs in agriculture; and *ii.* by limiting the measurement of changes in carbon stocks to after 2008, the Protocol provides no incentives for early adoption of carbon-sequestering land uses and management practices.

2.3 SBSTA8

In keeping with Article 3.4 of the Kyoto Protocol, negotiations about the inclusion of additional sinks activities were continued at the SBSTA meetings in Bonn, Germany in June, 1998. Although no firm decisions about the inclusion of agricultural sinks were made, SBSTA did conclude that LUCF actually represents three categories: land-use, land use change, and forestry (SBSTA, 1998). The explicit inclusion of land-use acknowledges that activities other than forestry and RAD (i.e., agriculture and agricultural soils) can have both a source and a sink term.

SBSTA8 resolved the uncertainty, arising from Article 3.3 of the Kyoto Protocol, as to when CO_2 removals in sinks are to be measured. Changes in carbon stocks will be measured over the first commitment period, as stocks in 2012 minus stocks in 2008 (Bruce et al., 1998). Which means that countries will count net CO_2 removals or emissions, as changes in carbon stocks that occur between 2008 and 2012 for RAD activities that began after 1990. An increase in carbon stocks from net CO_2 removals from 2008 to 2012 from RAD will be subtracted from emissions over the same period, whereas a decrease in stocks must to be added to the emission total.

3. IMPLICATIONS FOR AGRICULTURE

Information about GHG accounting for agriculture is provided from several sources: *i.* the agriculture and LUCF sectors of the category IPCC guidelines; *ii.* the Kyoto Protocol, Article 3.3, which limits sinks activities to forestry and RAD; *iii.* Kyoto Protocol, Annex A which lists agricultural soils as a source in the agriculture sector; *iv.* Kyoto Protocol, Addendum, Decision 2 which reaffirms that parties should use the Revised 1996 IPCC Guidelines for National GHG Inventories; and *v.* SBSTA8, which defined LUCF as land use, land use change and forestry. No clear picture of how GHG accounting for agriculture emerges from these various sources of information, taken together. Predictions about how Canadian agriculture will be affected vary, depending on how the IPCC, Kyoto Protocol and SBSTA decisions are interpreted. Outstanding issues that could have implications for Canadian agriculture include: *i.* the uncertainty about whether changes in carbon stocks in agricultural soils will be counted; *ii.* the consequences of measuring changes in carbon stocks only after 2008; and *iii.* the lack of whole system accounting for GHGs in agriculture.

3.1 CO_2 Accounting and Agricultural Soils

There is uncertainty about whether and how changes in carbon stocks in agricultural soils will be counted. Removals of CO_2 in agricultural soils cannot be counted as *sinks*, but it is not clear whether agricultural soils are to be counted as a *source* of CO_2 in the baseline year. If changes in carbon stocks (emissions or removals) from land use and management

are limited to RAD activities in Article 3.3 of the Kyoto Protocol, it would follow that changes in carbon stocks from other activities, such as agriculture, would not be included. However, if the limitations are assumed only to apply to removals (positive changes in carbon stocks), then emissions (negative changes in carbon stocks) from agricultural soils would be included with other sources.

The interpretation is important because if agricultural soils are a *source* of CO_2 in the base year, any activities that reduce emissions of CO_2 (i.e, carbon sequestration associated with farming practices such as zero-tillage or forage production) during the first commitment period (2008 to 2010) would contribute to Canada's reduction target, whether or not agricultural sink activities were recognized in the Kyoto Protocol. Alternatively, if agricultural *sinks* are allowed, CO_2 removals associated with agricultural activities undertaken after 1990 could be used to offset emissions in the first commitment period (2008 and 2012).

The worst case scenario for Canada, where adoption of carbon-sequestering farming practices is on-going and could increase in the future, would be the total exclusion of agricultural soils, as sources or sinks, from the LUCF sector. If soils are excluded, carbon sequestration and the associated emission reductions from soil conservation farming practices that occur after 1990 could not be counted. Although this is only a problem in terms of target reduction and GHG accounting (the environmental and production benefits of increased soil organic matter would be real) it could act as a disincentive for adoption of conservation practices by farmers and in domestic agricultural policy.

If removals in agricultural soils are allowed, the extent to which agricultural activities that could act as sinks would be limited (as the forestry sector is limited to reforestation, afforestation and deforestation activities) is unclear. For example, would agricultural activities that could act as sinks be limited to changes in land management (i.e., from conventional tillage to zero-tillage or permanent cover) after 1990? The limitation of sink activities to specific practices adopted after 1990 could create the "Kyoto Farm", which represents the agricultural lands on which sink activities are being practiced. Carbon

sequestered on the "Kyoto Farm" during the commitment period could be subtracted from emissions for that period.

If carbon sinks in agricultural soils are to be accepted internationally, countries that want agricultural sinks included, like Canada, need to show that it is possible to measure changes in the carbon stock of agricultural soils in a transparent, reliable and verifiable way. It could be argued that if emissions from agricultural soils are to be counted as a source in the 1990 base year, it does not make sense to exclude removals in soils for measurement and verification reasons. Methods for measurement of CO_2 flux from agricultural soils should apply equally to emissions and removals.

3.2 Changes in Carbon Stocks from 2008 to 2012

Carbon removals that result from sinks activities started after 1990 can be counted for the period 2008 to 2012. For example, the increase in the carbon stock associated with tree planting as part of a reforestation program that began in 1991 will be measured as the stock on December 31, 2012 minus the stock on January 1, 2008, and can be subtracted from emissions for that period. The carbon stock accumulation from 1991 until 2007 cannot be counted.

Carbon accounting only after 2008 could act as a disincentive to the early adoption of carbon-sequestering farming systems (i.e., before 2007) and tends to reward the late-adopter. In agriculture, because the rate of carbon sequestration is greatest when conservation practices are first adopted, countries that postpone adoption of until 2007 would be credited with relatively large carbon removals. In contrast, countries that promote the early adoption of soil conserving practices, for environmental health as well as carbon sequestration reasons, will be at a comparative disadvantage in terms of meeting their emission reduction targets.

3.3 Whole System Accounting and Agriculture Policy

The IPCC emissions guidelines are based on sector analyses which makes it difficult to do whole system analysis for a cross-sectoral activity like agriculture. Since emissions

from the manufacture of crop production inputs (fertilizer, pesticides, machinery) are counted in the industrial sector, and emissions from fossil fuels used in crop production or transportation are counted in the energy and transportation sectors, the IPCC framework does not account for GHG emissions from a whole farming system and cannot be used for comparisons among systems. The IPCC accounting system provides estimates of gross emissions for each sector, which are suitable for their inventory purpose. However, gross estimates provide incomplete and misleading information about the net differences among systems. For example, emissions from systems of livestock production and grain production will differ, depending on whether only on farm emissions are included (agriculture sector accounting) or if total system emissions (from on-farm crop production and the manufacture and transport of inputs) are included. The large amount of CH_4 produced by livestock puts cattle production at a disadvantage compared to grain production if only on-farm emissions are counted. However, if emissions from the energy required to produce and transport fertilizer and pesticide inputs are included in the calculation, the relative difference between grain and livestock production is reduced.

The IPCC accounting system cannot be used to determine net emissions from farming systems. Net emission accounting has to include emissions associated with activities in the agriculture, transportation, energy, and industrial sectors that are associated with crop production. Without information about net emissions, policy makers cannot know which systems produce the least GHG emissions or sequester the most carbon.

It is also important to recognize that policy analysis requires, not only whole system data, but complex systems modeling. A 10 percent reduction in the livestock herd cannot be assumed to result in a 10 percent reduction in methane and GHG production. A change in the size of the livestock herd will cause other changes throughout the agricultural system, perhaps an increase in crop production and N_2O emissions from fertilizers, that offset the reduction in CH_4 production from the smaller livestock herd. The IPCC guidelines will provide adequate inventory data, but are not adequate for development of domestic agricultural policy.

4. REFERENCES

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